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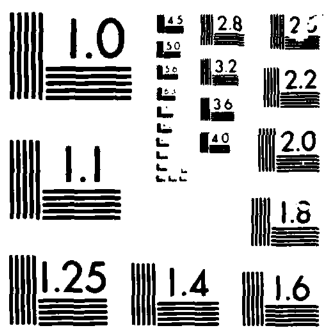

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DIGITAL MAPPING : FACT OR FICTION!

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ABSTRACT

The Defense Mapping Agency has passed the point where we provide only the traditional paper maps and charts used by the Armed Forces. Many of the traditional, manual, labor intensive production processes currently in use are no longer cost effective in supporting present readiness requirements. DMA is now heavily into the production of digital data to support the navigation and guidance requirements of new advanced systems. To meet the ever increasing sophistication of these new systems, as well as updating our capability to support our traditional products, DMA is in the midst of the most ambitious modernization in the history of cartography. While the all digital softcopy production system is today still a fiction, the Defense Mapping Agency has committed itself to make this fiction a fact by the early 1990's. Keywords; high resolution; user needs.

DMA MISSION

The Defense Mapping Agency (DMA) was formed in 1972 from a consolidation of separate Service mapping organizations. It employs approximately 9000 people in over 50 locations around the world with headquarters at the U.S. Naval Observatory in Washington D.C. The major production sites are the Aerospace Center in St. Louis, Missouri and the Hydrographic/Topographic Center in Brookmont, Maryland. The Aerospace Center is charged with supporting aerospace navigation while the Hydrographic/Topographic Center is charged with topographic mapping and the hydrographic charting of the seas.

Current production processes for paper maps and charts are labor intensive and therefore very costly. Nevertheless, DMA has the requirement for the annual production and distribution of more than 50 million copies of paper maps and charts for military and Merchant Marine use which will continue for many years to come. In addition, requirements for crisis response, increased accuracy, flexibility, and the worldwide commitment for DMA products have driven DMA to evolve from labor-intensive manual production processes to an interactive computer graphics emphasis as a means of decreasing production costs as well as increasing productivity.

The automation of feature extraction tasks, to the extent they can be accomplished, will help reduce costs. The resources required for information extraction and the relative benefit to be gained from automation can be expressed in Fig 1. If DMA could use more image based products in the generation of our products (no feature extraction, no symbolization, etc) the manpower and calendar time requirements would, of course, be greatly reduced. It is only as we build to the abstract (traditional map and chart products) that causes a high expenditure of resources for the symbolic representation of the map/chart feature data. This relationship is reflected in the accumulated effort curve in Fig. 1. Hence, the goal of automation.

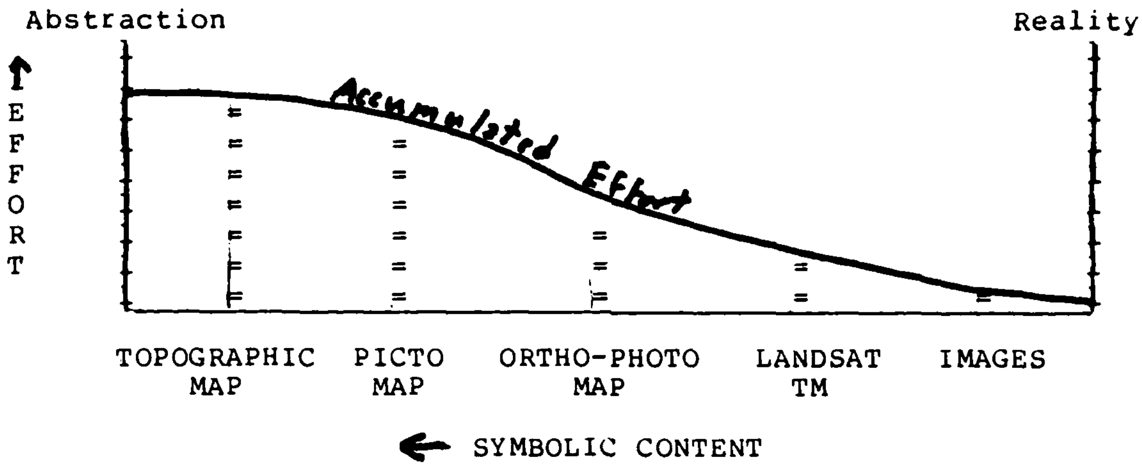

FIG 1.

MODERNIZATION

To support increasing demands for DMA products, a major expansion of the Agency's extensive computer capability has been undertaken. This modernization effort has the goal of a 50% reduction in production hours and a 75% reduction in production throughput time for the generation of currently defined products.

Computers will be applied to all map/chart production process, including source analysis, data collection, compilation, editing, maintenance, storage, and output. Many of the technologies and techniques (hardware, software, production processes) planned for the modernization are already in existence today. They will be integrated into a softcopy production system for the digital manipulation of map/chart data from initial source analysis to final reproduction. Advanced digital workstations will be developed to handle digital, graphical, and textual data. These workstations will

be the cornerstone of DMA production in the 1990's. Cartographers will be able to maintain strict interactive control over the development of digital data into the required format for output - either for insertion into the cartographic data base or for the generation of product masters according to specifications of the map/chart or special digital product required.

Critical to the successful implementation of the modernization is that DMA implement a standard computer operating environment to include hardware, software, operations and maintenance. Common hardware (mainframes, minicomputers and components for interchangability) and commercially available software, will provide for increased system reliability, reduced software maintenance, simpler operations and training and a better configuration management control over continually evolving system growth.

Development of a DMA all-digital capability will also require a transformation of existing production line techniques and significant training of personnel. In addition, a sophisticated on-line information management capability will be required, along with state-of-the art laser and fiber optic communications capabilities for transfer of expected massive volumes of data. It is essential that these developments be designed to be cost-effective given system and program requirements. Furthermore, evolving technologies that offer significant improvements in cost/performance over the baseline system will continue to be of interest for subsequent exploitation.

Effective management policies for modernization will address responsibilities for developing plans, programs, and schedules to enhance DMA's capability to exploit data extraction from source materials and to enhance product generation from the MC&G data base. Rule sets are to be designed to aid the production planning process for the translation of user requirements into production assignments. They would specifically address user requirements vs resource availability. A Multi-Product Operations (MPO) concept is being designed into the modernization program and extraction specifications will be essential to its success. Source selection would be based on the most stringent extraction requirements for all DMA products within a specific geographic area. DMA could collect data from a single source and, in a single extraction process at the workstation, satisfy multiple products assigned within that area. The integrated MC&G data base would then support all product requirements.

Finally, the softcopy production system will be geared towards a topologically consistent digital data base to include all

cartographic feature and attribute data required to support DMA paper, film and digital products. The digital data base will have an expected data volume of 10^{17} pieces of information, with possibly 10^{13} bits accessible in near real time to multiple users. To understand the complexity of this undertaking, try to imagine every house, field, road, stream, fence (i.e., every feature in the data base) being available to the cartographer at his work station.

Special attention must be given to controlling any divergent growths of digital data base requirements. Differences among data specifications for current and projected users of our digital data base must be resolved. Successful data base interoperability among DMA users will require implementation of a "standardized" digital data base. DMA must develop and implement this digital data standard in its modernization and then "encourage" users to conform to it. It should be noted that user impact on DMA resources is very nearly proportional to the proliferation of unique formats requiring tailored composition and non-standard accuracies. Validation of such esoteric requirements can cause a significant displacement of the level of production resources available to DMA to support our standard product requirements. Emphasis must therefore be directed toward innovative means to significantly reduce the time required to produce the digital data base. Because of limited production resources, DMA can realistically only generate and support one major set of digital data. DMA cannot maintain a responsive and cost effective production posture if required to transfer its data to unique user requirements. All future system developments should address our data format and content (unless required at a higher resolution than we can realistically provide) for exploitation.

To address the immense data base issue, DMA development is centered on efforts related to data base structures and the computer architecture to handle the spatial data efficiently. Further exploration of data base management systems will be required to develop spatial query capabilities for data bases which may be geographically dispersed and which must deal with concurrency, integrity, and multi-level security.

RESEARCH AND DEVELOPMENT

Continuing expansion of this country's strategic arsenal and increased force readiness requires DMA to continually expand its capabilities for weapons systems support. DMA's role in research and development has been expanded accordingly, and significant advances have kept the Agency at the forefront of some of the most radical changes in state-of-the-art technology in digital data processing, photogrammetry, cartography, geodesy and photography. The Agency, however, is still a long way from solving the total digital production problem. For

this reason DMA continues to support R&D programs in the areas of automated feature analysis and mass database management. With respect to the feature analysis problem, automated feature extraction is an important DMA goal. DMA has developed an in-house research test bed which adapts techniques developed by researchers at various academic institutions and has contracted with a number of universities to explore various areas of image understanding. These problems encompass automated recognition of both man-made and natural features, change detection, and the knowledge base to properly identify these features and insert them into the spatial data base.

Automated change detection is another important goal. It is desirable to be able to identify changes between images, and between images and graphics files. There are ongoing developments in the modernization effort that are also expected to achieve a high degree of automation in elevation data extraction.

Modernization is addressing this by evolving a framework addressing a number of processes central to the automation of feature extraction, and a knowledge-based system is being built to address feature identification and attribution requirements. Rule sets will also be developed to aid the cartographer in his development of the data. Rules will be developed to support both data extraction and product finishing functions. Data extraction would include processes to be executed during photogrammetric and cartographic feature and terrain extraction. Product finishing would address those processes for the extraction of data from the MC&G data base to support rule-based product symbolization. Included would be such automated cartography functions such as line generalization, names placement and symbol generation. Such a system of rules must interact with both a human analyst and a spatial knowledge base.

DMA's major interest for a near term solution is in cost-effective, interactive approaches to the processes of image segmentation, region measurement and feature identification and attribution. The initial focus should be on effective interactive techniques. Final modular software design would allow for new algorithms to be easily plugged in. Past experience with many algorithms designed for total automation have shown that awkward manual clean-up is often required. If efficient interaction is designed from the start a better system will result. DMA needs to orient to specific objectives. We do not have the resources to test every algorithm that could possible relate to every situation. DMA needs to develop benchmark testing materials to evaluate current production facilities as well as commercial development. A new generation of sophisticated systems are being developed to automatically perform the functions of pattern/symbol/character recognition, feature tagging and

spatial coding. Viable benchmark data would form the basis against which proposed evolutionary changes could be effectively evaluated.

The mass database management objective includes developments in storage media, database structures, data compression, interoperability and interactive data base storage, access and management with a variety of user interfaces. Successful development of these capabilities is crucial to cost effective support of future requirements for digital data production. Storage of digital data is another major problem and continues to be the subject of a vigorous research and development effort. Optical disk and high-density magnetic cartridges are under study, along with other techniques. Another critical component in support of new navigation and guidance systems is the ability to provide adequate digital databases that describe a variety of types of surface information. Both static and time-varying information such as texture, thermal and near-infrared properties, precise geometric properties, population and traffic density patterns, and atmospheric weather data may be required in addition to traditional feature attribute descriptors. Along with new types of feature descriptors, increased resolution and level of detail will also be required. Numerous technical problems must be solved in the areas of artificial intelligence, image understanding, telecommunications, and digital production techniques. DMA has accepted this challenge and is actively pursuing university, government, laboratory and commercial contractor support.

FEATURE EXTRACTION

The introduction of the digital working environment in the early 1990's will facilitate increased levels of automation. In this environment the feature analyst will use digitized imagery at a softcopy workstation instead of film and optical equipment. The analyst will have computer-based automatic and interactive aids for extracting features.

This digital production environment will make it possible to incrementally introduce new levels of automation. Maturing research in several areas are candidates for incorporation into the production process. Automated symbolic change detection will help the analyst rapidly evaluate new source material. Automated analysis of airport scenes and automated extraction of transportaton networks such as roads and railroads are two domain specific areas of research showing promise.

DMA is addressing the feature extraction problem in a Technology Base Program because of the potentially high payback to be achieved from a modest increase in capability. In the longer term, the major focus of the DMA Technical Base Program is to automate the information extraction function by introducing knowledge-based techniques and by developing

machine intelligence systems. DMA has a joint program with the Defense Advanced Research Projects Agency to extend the image understanding technology into intelligent machine applications. The efforts include the development of expert systems, a natural language man/machine interface and automatic creation of a spatial knowledge/data base. Also, fiscal year 1985 was the first year of an exploratory development program of research in computer vision for which DMA has direct management responsibility. This program is addressing many of the problems which must be solved in order to achieve the ultimate goal of development of a robust fully automated feature extraction system. These problems include improvement of line detection algorithms, exploitation of multispectral data, increasing computer processing speed and efficiency, and the development of artificial intelligence techniques specific to MC&G feature analysis from imagery.

It should be noted that current industry research in the feature extraction problem tends toward recognition of specific features (i.e., vehicle on road, ship in port, etc.) and industry subsequently tends to discard any additionally extracted information as noise. It happens that this noise, the road itself, the house next to it, the vegetation across the road, etc. is actually the data DMA requires for input into the MC&G data base.

Approximately 80% of the cost of our current Feature Analysis program is in the feature analysis interpretation problem. The hardest job is the interpretation of unique significant features. We know that the feature is a bridge, but what kind of bridge is it? A manual, labor intensive feature interpretation production process is our current solution to this requirement. Should DMA achieve even a modest increase in capability, this increase applied to an approximate 5000 man year estimate for Level II (cultural feature data at a scale of 1:50,000) coverage for cities currently in our Level I (250;000 scale) data base, would effect a significant savings in both manpower and equipment resources.

DMA has developed a Feature Analysis Coding Standard (FACS) to include all attributes required for products. FACS will contain a standard code assigned to each feature in the extraction specification. A FACS coding system also exists for attribution. FACS will support the density of features required in each product specification and the rules for collection of data to support MPO operations. These rules will have to be followed to achieve a seamless data base from adjacent areas collected under different product specifications. Collection of MC&G data independent of these rules, will obviously yield mismatches to adjacent data sets in terms of feature connectivity and feature densities. There will undoubtebly be some feature and density requirements that will be exceptions based on the spatial properties of the data

(i.e., sparse areas, overcongested areas, representation of data in built up areas, etc.). These exceptions should be allowed.

ADDITIONAL AREAS FOR EXPLOITATION

The Terrain Analysis Data Base (TADB) being developed by DMA will support trafficability, cross country movement, and most MC&G requirements in the tactical arena. Some gaps do occur, however (i.e., soil types, slopes and grades, river velocity and other items not available from current techniques of feature extraction from the digital sources), and DMA will need to address these areas. DMA is planning a scale of 1:50,000 for its TADB. The U.S. Army has a recently identified additional requirement for 1:12,500 scale data for terrain analysis data. In addition, a systematic approach is needed for the rapid preparation of local-area, demand-driven digital terrain databases. Efficient methods are required to get this information to the user. Knowledge-based applications are long term potential solutions.

A number of computer scene enhancement techniques such as synthetic breakup and fractals should also be considered as potential methodologies to support simulation and terrain modeling requirements. Synthetic breakup is a technique to put realism into the scene where precise metric capability is not required. It would allow maximum use of our Level I culture data to support varying product requirements via the synthetic break up of large aerial features into smaller ones based upon original feature attributes. Real features would not be discarded and unrealistic feature representations (due to changes in scale, feature density, etc.) could then be represented in a realistic manner. Current labor intensive production resources limit the collection of high-resolution data to small geographic areas of interest and the production of large area, high-resolution databases will continue to be unattainable without both adequate source data and automated feature extraction techniques. Synthetic breakup will have its greatest utilization in areas where feature density is sparse and Level II culture data collection requirements will be no more expensive than for Level I.

Terrain modeling in an important element for representing feature data. Fractals offer a promising approach. Fractal sets have recently become popular for the description of natural features used in image analysis, image simulation and topographic modeling. As with synthetic breakup, fractals are considered a potentially cost effective means for providing additional background data where metric quality is not required. An approach is to generate metric quality data for unique features required for navigation by the users, and then fill in the remainder of the scene with non metric data. Fractals are a potential mechanism.

Application of remote sensors such as Landsat, airborne active/passive scanners and synthetic aperture radar to digital data collection represents a new and promising generation of technology that can be exploited to improve digital data production at DMA. Forthcoming multisensor imagery from systems such as the French SPOT and the U.S. EOSAT will be at a 10 meter pixel resolution. Such imagery will support many map and chart requirements as well as support production planning for maximum currency.

An additional advantage of multispectral imagery is that the interpreter has the option of single-band black and white or color composites (the color assignment and bands used being options) and ratios of any combination of bands. He also can use various grey level assignments and classification systems to aid in interpretation. The greatest advantage of space-derived images is the greater synoptic perspective. Just as the aerial camera expanded the cartographer's perspective for analyzing the character of the earth's surface, space imagery enlarges this perspective even more.

Another goal is to expand multi-source registration capability to include visible, Landsat, radar and any other sensor and graphical information. We want to be able to generate conjugate points automatically (correlation, edge matching, etc.) in order to synergistically exploit these sources for MC&G product support.

A sensor with a specialized standoff role is the side-looking airborne radar (SLAR). From high altitudes, SLAR antennae can collect self-generating radar energy from either side of the aircraft. The film is not affected by poor weather conditions where persistent cover precludes conventional photography. Radar provides its own controlled source of illumination and can be used at any time regardless of sun illumination. Radar images are especially useful for emphasizing topographic relief because of the strong shadowing effect that can be obtained.

Synthetic Aperture Radar (SAR) imagery from SEASAT and Shuttle Imaging Radar systems will also support many mapping requirements. Good stereo viewing calls for a limited change in position of the images and texture while good metricity calls for greater changes in imagery. The system would have to be tasked for optimal data collection against any validated requirement. Effective use of multi-source data will be important to our goals of automating feature extraction and change detection.

Finally, there are ongoing developments to merge digital source data with our Digital Terrain Elevation Data to generate synthetic low level perspective scenes from any point at any angle. A major need is to simulate selective DMA cultural

feature data on these perspective scenes in order to provide a greater level of realism for planning, training and simulator applications.

CONCLUSIONS

DMA is being tasked to support an ever increasing number of higher resolution requirements from our users and the question is how can DMA practically and cost effectively support such requirements? In order to maintain a viable production status in the future, DMA must ensure the use of standard DMA products to support new operational doctrine, new systems or modifications to existing systems. The use of standard DMA products is essential to minimize disruption of MC&G production commitments to established operational requirements. New MC&G support requirements must be defined early in the concept definition phase of system development. As each new system progresses through the development and acquisition process, the required DMA product must be identified and the appropriate resources allocated to support it. Any proposals for unique, non-standard product support must be reviewed to determine viability of the requirement and to consider possible alternative means of satisfying the requirement.

DMA has embarked on an ambitious modernization program to automate its production processes. DMA will also continue to utilize laboratory, university, and commercial assistance in the interpretation of MC&G requirements and for the development of alternative products, production concepts, and techniques for providing the required MC&G support at minimum cost. Full automation, however, will not be an achievable goal at this time. The feature analysis/feature interpretation problem will be with us through the 1990's. R&D goals have been initiated to continually address this problem, along with the investigation and development of efficient methodologies for exploiting multi-sensor imagery. On-going developments in knowledge-based systems will be monitored for subsequent exploitation by DMA.

The state-of-the-art development of our modernization will be a great step forward for DMA. DMA must not lose the momentum gained through this effort. We must be ever cognizant of the requirements of our mission and expend the energy and resources required to achieve it. The critical role of the human operator in the production of digital data is not expected to change. The cartographer of the 1990's will require skills and familiarity with computers, knowledge of mapping, charting and geodesy, an understanding of source materials and an understanding of production processes. The DMA digital mapmaker of the future will be ready and capable to implement applicable any and all improvements into the established framework of our modernization program.

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